

PFP's – Proven Asset Protection

Ian Barry, formerly of specialist product manufacturer Cafco International, explains how costly equipment and structures can be fire protected using a variety of materials and gives examples of recent events.

Unfortunately, fires are not at all unusual events in high-risk installations such as petrochemical and chemical plants. They are also usually far more severe than the type of fires normally associated with those that occur in buildings where cellulosic materials are ignited and apart from life safety, one of the most important issues that any operator must consider, is the protection of the asset itself.

It is generally acknowledged that the most effective method of protecting a structure or a storage vessel against the effects of a fire is by passive means, utilising coatings, cladding or pre-formed arrangements of materials that are capable of retarding the passage of heat into a structure during fire exposure.

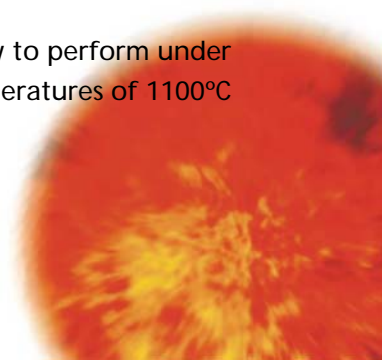
These Passive Fire Protection materials (PFP's) are applied to steel and concrete equipment structures and pipe racks as well as storage vessels and their supports in order to maintain their stability and integrity when exposed to high intensity fires.

On an onshore installation, a number of different fire scenarios can occur simultaneously and if no passive fire protection measures have



been taken, the effects of a serious fire can be catastrophic. A fire might start with the ignition of a flammable substance leaking from a flange or a pump and develop rapidly as it is fed by the supply of additional fuel as the leak continues. As the temperature of a loaded steel supporting structure increases, its strength weakens to the point at which it will collapse. In the case of a pressurised storage vessel, the weakening of the vessel wall can result in a BLEVE (Boiling Liquid Expanding Vapour Explosion) as the internal pressure inside the vessel exceeds the strength of its weakened steel shell.

From the scenario described, it follows that any applied PFP should have the ability to perform under both POOL FIRE and JET FIRE conditions where flame temperatures can reach temperatures of 1100°C and 1500°C respectively with heat fluxes up to 350Kw/m².



When concrete is exposed to fire, pressure within the matrix increases as the combined moisture turns rapidly into steam. When the pressure exceeds its strength, explosive spalling occurs exposing underlying layers of concrete to the fire. As the process continues, rapid deterioration of the structure can occur, exposing the steel reinforcement and major repairs are often required after a fire resulting in long shutdown periods and loss of revenue for the operator whilst the concrete is reinstated.

The susceptibility of concrete in fires is illustrated in this photograph showing the tunnel lining after the Channel Tunnel fire that occurred in 1996. The fire lasted for approximately 5 hours during which time extensive spalling occurred. The concrete lining thickness was reduced from 40cm to 2cm in the worst affected area and the tunnel was closed for more than six months whilst the repairs were carried out.



In the Mont Blanc tunnel fire that occurred during 1998 when a truck carrying flour and margarine ignited, the damage to the concrete lining was so severe that the tunnel remains closed today.

The application of a fire protective coating will limit the rise in temperature of a structure or a vessel to below its critical temperature in a fire and will also prevent rapid heating of a concrete structure or tunnel lining, reducing the risk of the spalling phenomenon from occurring. A fire protective coating could have been applied

to the linings of both the Channel and the Mont Blanc tunnels for less than 10% of the cost of the repairs subsequently required.

PFP's have been used extensively on refinery complexes for many years and have also been applied on the concrete lining of the recently opened Øresund Tunnel that forms part of the fixed link between Denmark and Sweden. The application of PFP's is mandatory in tunnels carrying hazardous goods in the Netherlands and their benefits are now being recognised for tunnel applications throughout the world.

PPF materials and systems

Many types of PFP materials exist and their performance in real fires will vary due to the way in which each material performs its fire protection function.

Selection of a suitable material must take the particular risk into account and would usually consider some or all of the following points:

- Strength
- Durability
- Low added weight
- System integrity
- Non-corrosive
- Non-hazardous
- Ease of installation
- Cost effectiveness
- FIRE PERFORMANCE

The most common types of PFP materials applied in high-risk installations are:

Inorganic coatings

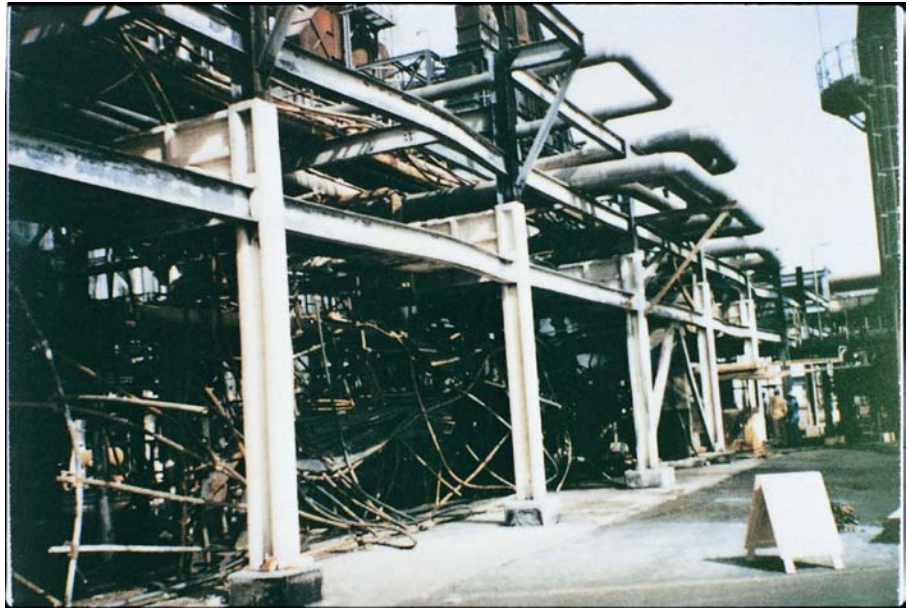
These are the most widely used coatings with many millions of square metres applied on structures and vessels throughout the world. The materials are usually based on cement with a lightweight insulating aggregate of exfoliated vermiculite that provides exceptional dimensional stability under hydrocarbon fire exposure conditions.

The exfoliated vermiculite has the capacity to relieve the stresses created by both hot and cold thermal shock when the coating is subjected to simultaneous fire and hose stream impingement. It also provides the insulation characteristics of the material. All PFP's function by limiting the temperature of a structure or vessel below its critical temperature over a specific period of fire exposure.

A major advantage of this type of coating is its ability to provide a predictable level of protection beyond this point. This was demonstrated recently in a major incident in a refinery complex in the U.K. where the fire continued for almost seven hours with no loss of the structures or vessel supports even though design fire rating was specified for two hours exposure.

Evidence exists to show that vermiculite cements can perform equally as well in multiple fires where no repairs or reinstatements have been carried out. This facilitates minimum plant shutdowns after minor fire incidents with a minimal loss of revenue for the operator. Many incidents have occurred in installations in the U.K. and throughout the world over many years.

Structures protected with Fendolite MII after a major fire at the BAPCO Refinery in Bahrain. In this fire, which continued beyond the specified period of protection, no structures were lost and rebuilding time and associated costs were kept to a minimum since no primary structures had to be replaced.



Other examples of the effectiveness of passive fire protection are illustrated by incidents at KNPC in Kuwait where a recent fire in the Isomax unit lasted for 24 hours and at Yukong Oil in Korea where a fire occurred following ignition from an oil pump leakage during commissioning. No loss of structure occurred in either of these incidents.

Fendolite MII is now also used by a major refinery operator in the U.K. to protect primary concrete structures against fire. In a recent incident, severe explosive spalling of the concrete occurred under fire exposure resulting in a long and costly shutdown period whilst the pipe racks were reinstated. Fendolite MII will reduce the rate of temperature rise within the concrete and therefore prevent explosive spalling from occurring.

Damage to unprotected pre-cast concrete following its exposure to a hydrocarbon fire. More than 200mm of concrete have spalled leaving exposed steel reinforcement and pre-stressing bars.



Vermiculite cements are non-corrosive to the substrate or surfaces of a vessel and since they are non-combustible do not produce any toxic fumes during their exposure to fire. They can therefore be used where life safety is a primary consideration and are particularly suitable for application onto steel and concrete tunnel linings where high intensity fires can severely damage the structure of the tunnel and threaten lives.

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The only perceived weakness of vermiculite cements is their susceptibility to mechanical damage because of their perceived low density compared to that of concrete. In fact their strength and durability is adequate for most applications including off-site application to pre-assembled modules and single steel sections prior to their transport to site.



Organic coatings

Organic coatings are thin compared to vermiculite cements and are generally considered to be more durable as far as resistance to mechanical damage is concerned. They fall into one of the following groups:

Intumescent mastics

Intumescent materials are normally epoxy based materials which when subjected to fire exposure, expand to form an insulating char with a low thermal conductivity acting as a thermal barrier between the fire and the substrate. During this reaction, toxic fumes and smoke are released at temperatures above 300°C which makes them unsuitable for use in enclosed areas like accommodation modules and Temporary Safe Refuges, where life safety is a major consideration.

Intumescent coatings have excellent adhesion to steel substrates and high impact resistance making them suitable for use in areas such as drilling modules and off-site applications where regular mechanical impact is likely.

They can be prefabricated into panels to form fire rated divisions and cast onto pre-formed metal chassis in order to provide protection to equipment such as Emergency Shut Down Valves (ESDV's) and actuators, allowing the safe shut down of a plant or process during the early stages of a fire and preventing escalation of the incident.

Ablative coatings

This type of organic coating gradually erodes under fire exposure due to the absorbed heat energy input from a fire that changes the virgin solid coating into a gas composite. This action prevents heat absorption into the substrate to which it is applied.

Like intumescent materials, they are resistant to mechanical damage but the application procedure is complex which contributes to relatively high application costs. The microporous char is also susceptible to damage from hose stream application during fire exposure.

Subliming compounds

The active ingredient in this type of coating absorbs heat as it changes directly from the solid to a gas phase (sublimation). As in the case of ablative coatings, intumescent are incorporated to provide an additional insulating layer.

The degree of protection provided by subliming compounds is a function of the temperature of sublimation for each particular compound, the thickness of the coating material, the heat capacity of the substrate and the degree and time of fire exposure.

By their very nature, all organic coatings are consumed by the action of fire and therefore once exposed for their prescribed period, provide no further protection to the structure. This can be a major disadvantage during fires of long durations.

No Statutory Regulations exist which cover the fire protection requirements for the hydrocarbon and chemical process industries. However, the benefits offered by the provision of adequate passive fire protection is recognised by all major operators and features in their individual Engineering and Safety Standards. All proprietary products and systems must undergo independent fire testing to acceptable Standards such as BS 476 Part 20 "Appendix" D – Hydrocarbon Curve in the U.K. or UL 1709 in the USA both of which utilise a hydrocarbon time/temperature curve representing burning hydrocarbons.

Although the various types of PFP coatings perform a similar function, selection of a suitable material should take account of the overall design requirements and it is not unusual to select a combination of different coatings and/or systems on the same installation.

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ABOUT THE AUTHOR

Ian Barry is an Incorporated Engineer and joined Mather and Platt in 1971 to become a 'Special Risks' Draughtsman in the Oil and Nuclear Industries. In 1977 he joined Preussag AG Feuerschutz as a Project Engineer in Kuwait, responsible for the installation of active fire protection systems at Doha Power Station. He joined Mandoval in 1983 and since 1998 (after the sale of Mandoval Coatings to Cafco International) is now specialising in the use of Passive Fire Protection in road and rail tunnels. He formed IEB Consulting Ltd in May 2001 which now provides fire engineering solutions and specialist project management.

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